Environmental Acoustic Support Plan for 2000 Multi-Static Active Sonar Program

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LONG-TERM GOALS

Contribute to the understanding of the dynamic environmental acoustics conditions in the littoral region off the coast of Korea and in the East China Sea where the Navy is implementing and transitioning multi-static active sonar technologies to the fleet. Of particular importance is the understanding of critical environmental parameters to sonar performance and transitioning these physical insights to tactical memoranda and rules-of-thumb.

OBJECTIVES

Provide the Multi-Static Active ASW program with environmental characterization in sufficient detail to ascertain the effects of two tactically important littoral environments (February 1999, off the east Coast of Korea in the Sea of Japan and August 2000, in the East China Sea) on the sonar system performance. In particular, environmental effects (oceanography and bottom geology) on ambient-limited and reverberation-limited conditions are emphasized. Measurements will be conducted to characterize (i) the spatial-temporal variability of the ocean, (ii) the acoustic environment via transmission loss measurements, and (iii) bottom reverberation.

APPROACH

We have provided the following for the East China Sea exercise: (i) pre-test environmental acoustic assessments and test plan inputs; (ii) at-sea environmental-acoustics data collection; (iii) analyses and physical interpretation of the effects of the environment on the Multi-Static Active ASW system performance; and (iv) tactical rules-of-thumb. First, we ensured that test planning for the two exercise utilized historical environmental data, combined with appropriate geoacoustic models for bottom loss. State-of-the-art propagation models were used to predict the system performance envelopes. This provided the experiment planner with knowledge of possible critical environmental factors that might affect the outcome of system testing within planned source, target and receiver geometries.

At-sea data collected were used to characterize the environmental variability. After processing, physics-based models were developed to assess how the environment impacted the system performance. For the Sea of Japan exercise, analyses were conducted jointly with BBN Technologies.

WORK COMPLETED

In June, 2000 the final joint BBN/OASIS report entitled "An Assessment of Distant Thunder Sonar Performance During SHAREM 127 (DTIV)" was issued documenting how and why the system performed during the exercise. The physical insights and lessons learned from this effort are being transitioned to ASTO for development of a tactical memorandum for fleet use to effectively use the multi-static sonar system off the Coast of Korea, in the Sea of Japan environment. In particular, these efforts have identified effective depth placements for the system sources and receivers.

In August, 2000 the SHAREM 134 system performance prediction report issued, entitled "Performance Predictions for MAASW/DT During SHAREM 134/DTVI." Historical environmental data for SHAREM 134 were compiled and distributed to modelers at ASTO and Naval Undersea Warfare Center. Propagation models were run using the predicted environmental data. A geoacoustic model was developed from inversion of transmission loss data measured by the Harsh Environment Program (HEP) in the East China Sea. Also, we collaborated with ONR PI's from the ASIAEX program to obtain recent oceanographic and bottom-related data to enhance our prediction model.

Revisions to the peer reviewers comments for the Technical Communication for the IEEE Journal of Oceanic Engineering (see Publications) have been completed during the spring and winter. Briefs were given to N84, SWDG, NAWC and ASTO describing system performance comparison in the East China Sea and Coast of Korea, Sea of Japan. Environmental acoustics results from the ECS will be documented in another IEEE JOE technical communication.

RESULTS

Figs. 1a and b show the synoptic sound speed profiles measured from the exercises in the Sea of Japan (February 1999) and the East China Sea (August 1999). For the system source depths used during the exercises, the downward refracting sound speed gradients present during the Sea of Japan exercise resulted in high bottom grazing angles. This coupled with a high loss bottom type resulted in high transmission losses. The bottom type for the East China Sea is low loss and the resulting transmission losses were much less than the Sea of Japan.

The impact of acoustic transmission through these high sound speed gradients off the shelf break was demonstrated during the exercise off the Coast of Korea, in the Sea of Japan. The resulting Sea of Japan high transmission loss environment is shown in Fig. 2 for shallow and deep sources. Also shown in the figure are transmission losses for the East China Sea. The relative system performance in both environments is noted in the figure by comparing the respective ambient noise limited Figure of Merit (FOM) detection range (denoted R_D). (The FOMs are based on typical values of ambient noise in these environments and assumed values for the sonar system parameters.) These results show that the system performance is much better in the East China Sea. Further, the results provide tactical guidance for developing system concept of operations (CONOPS).

In the Sea of Japan, the predicted performance agreed reasonably well with actual results due to bottom loss conditions, sound speed gradients and the presence of a strong oceanic shelf-break front. The Korean East Coast littoral environment is a complicated acoustical environment. The oceanography is dynamic, characterized by coastal shelf-break fronts and high spatial-temporal variability in the sound speed three dimensional sound speed climate. The bottom appears to be spatially variable, with sloped bathymetry. The East China Sea, with its low loss sandy bottom, results in a low transmission loss environment and effective overall system performance.

Fig. 3 shows a comparison of actual and modeled signal-to-interference ratio for an event in the ECS exercise. During this event, the system performance was limited by reverberation and the present reverberation model shows excellent agreement with the measurements.

IMPACT/APPLICATIONS

Operations in shallow water shelf regions are primarily sensitive to sound speed gradients and bottom type. The effects of bottom roughness and off-axis scattering and shelf break internal waves were not investigated due to limited data collection; however, these may further impact the degree of propagation loss experienced in this type of environment. It is known that bottom type changes rapidly from one location to the next over horizontal scales on the order of less than several kilometers. Most databases do not contain data of sufficiently high granularity or resolution to permit tacticians to adjust geometries for this scale of variability.

TRANSITIONS

The Multi-Static Active ASW System is currently being transitioned through the Advanced Systems Technology Office. Recognition of the impact of bottom type, sound speed gradient, spatial and temporal variability, and upslope vs. downslope vs. cross-slope directions on propagation is important for Tactical Decision Aid (TDA) development and the need for fast, range dependent predictive models. Present analyses are being used by ASTO in the development for a tactical memo for system operation in these environments and rules-of-thumb for effective source and receiver placements.

RELATED PROJECTS

1 - Littoral Warfare Advanced Development (ONR CODE 321 US), CDR Scott Tilden, Program Manager is supporting system development with a comprehensive set of environmental and environmental acoustic measurements to document and quantify environmental impact and variability.

2 - Environmental Effects in Naval Sonar Signal Processing and Performance (ONR Code 321 US), Nancy Harned, Program Manager is supporting the investigation of SHAREM data sets to determine the sonar signal processing and operational effects on detection performance utilizing the environmental data sets from these exercises.

PUBLICATIONS

The following paper has been accepted for publication as a Technical Communication in the IEEE Journal of Oceanic Engineering: "Effects of the Korean Littoral Environment on Acoustic Propagation," authored by P. Abbot, S. Celuzza, I. Dyer, B. Gomes, J. Fulford, J. Lynch, G. Gawarkiewicz and D. Volak.

The following articles have been accepted for publication in the Journal of Underwater Sound: "Multi-Platform Multi-static Active ASW Distant Thunder Exercise Results," by K. Brintzenhofe, R. O'Donnell, and P. Abbot; and "An Assessment of Distant Thunder Sonar Performance During SHAREM 127 (DT IV)," by P. Cable, P. Abbot, R. O'Donnell and S. Celuzza.

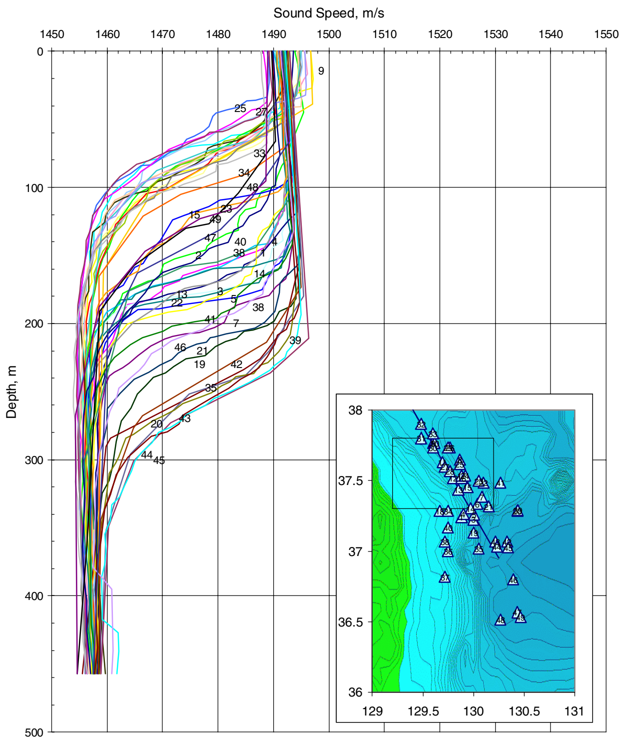

Fig 1a. SHAREM 127/DT IV Sound Speed Profiles N=48, over 4.5 days

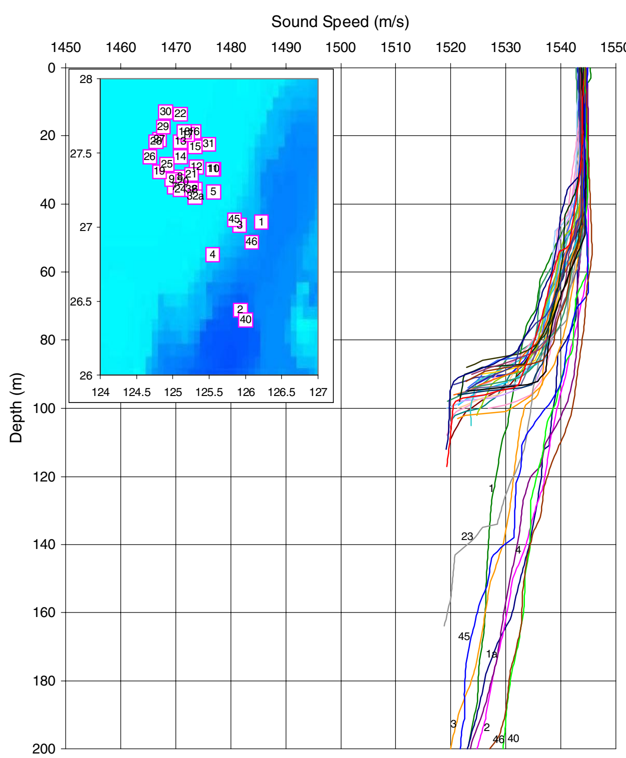

Fig 1b. SH130/DT V Sound Speed Profiles N=37, over 7 days

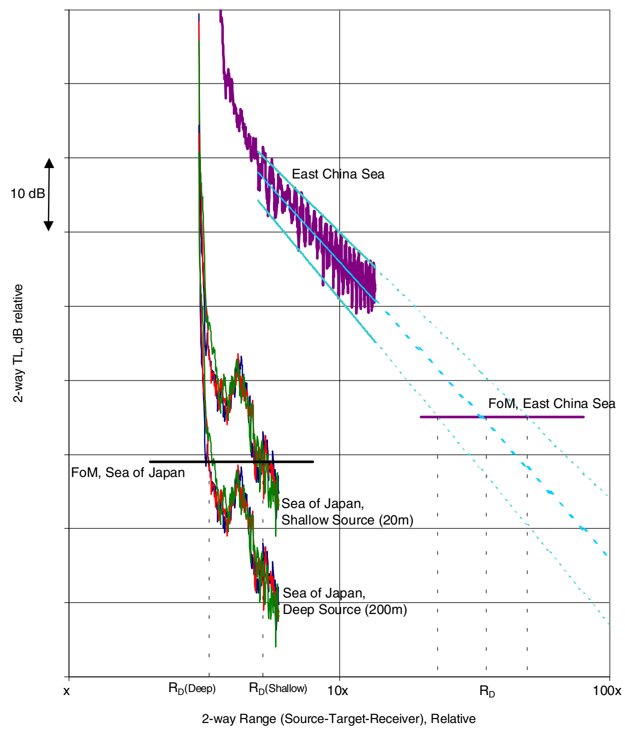

Fig 2. Multi-Static Active Sonar Ambient Noise Figure of Merit (FoM) along shelf in Sea of Japan (Shallow and Deep Source) and in East China Sea

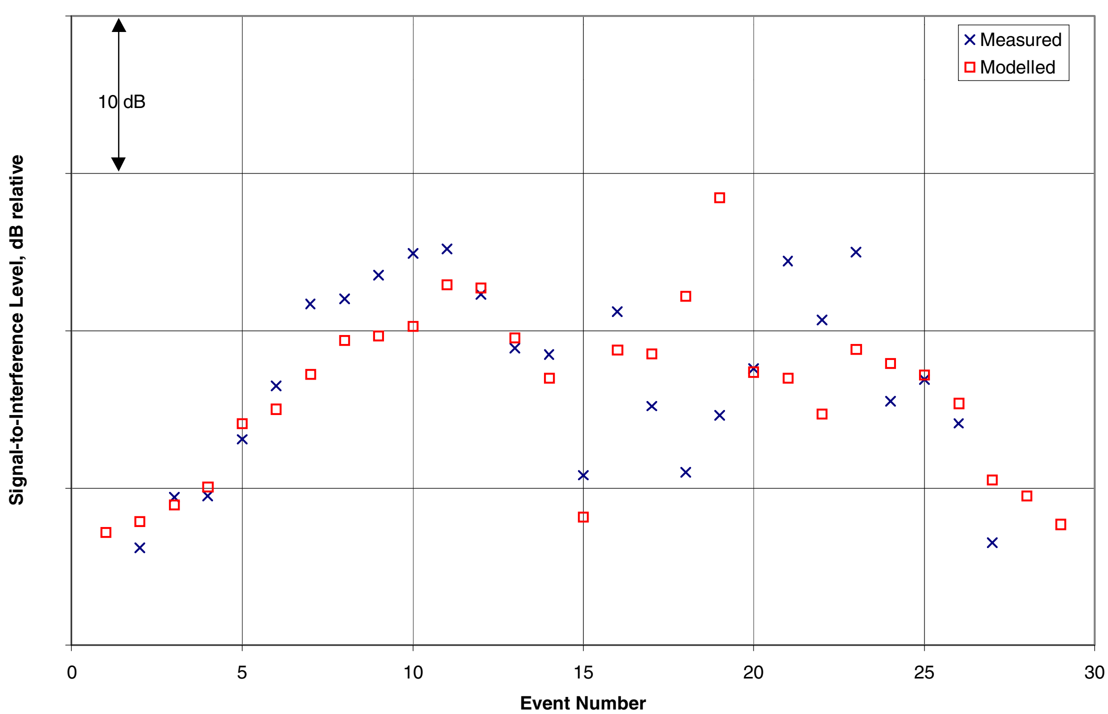

Fig 3. Signal-to-Interference Level for Multi-Static Active Sonar Performance in the East China Sea: Measurement and Model